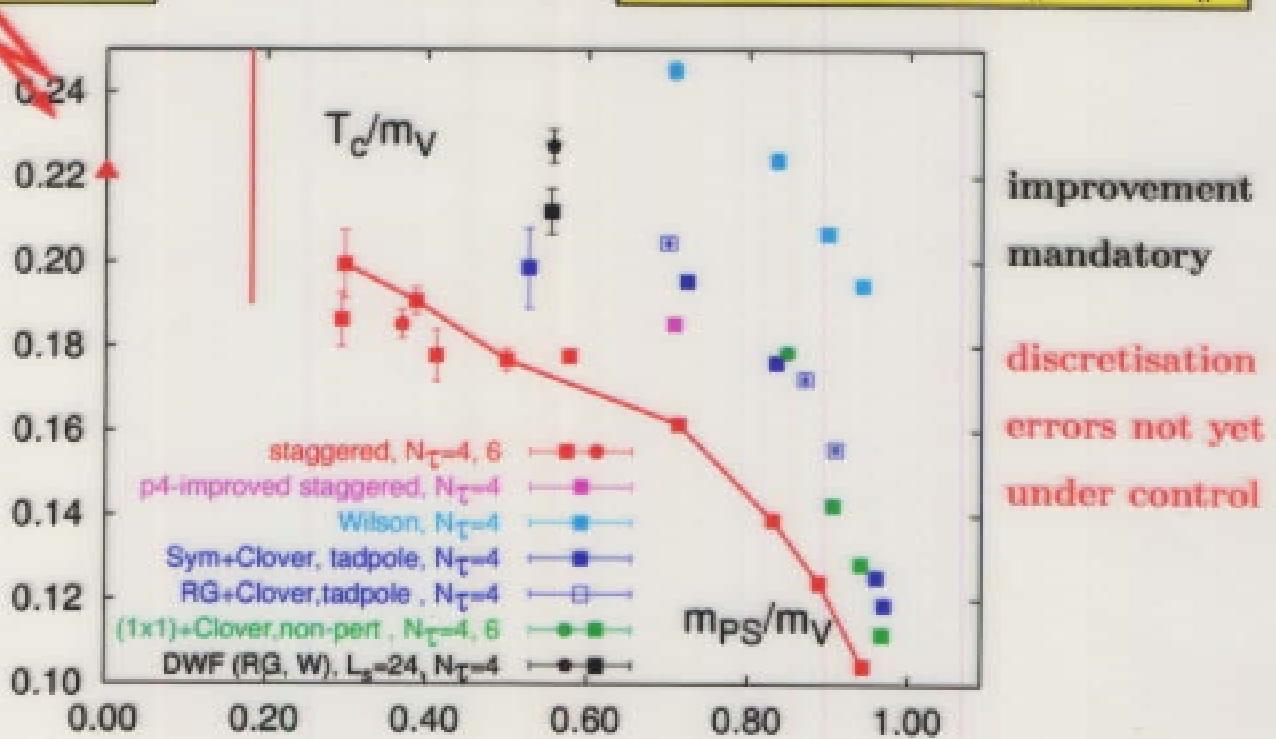
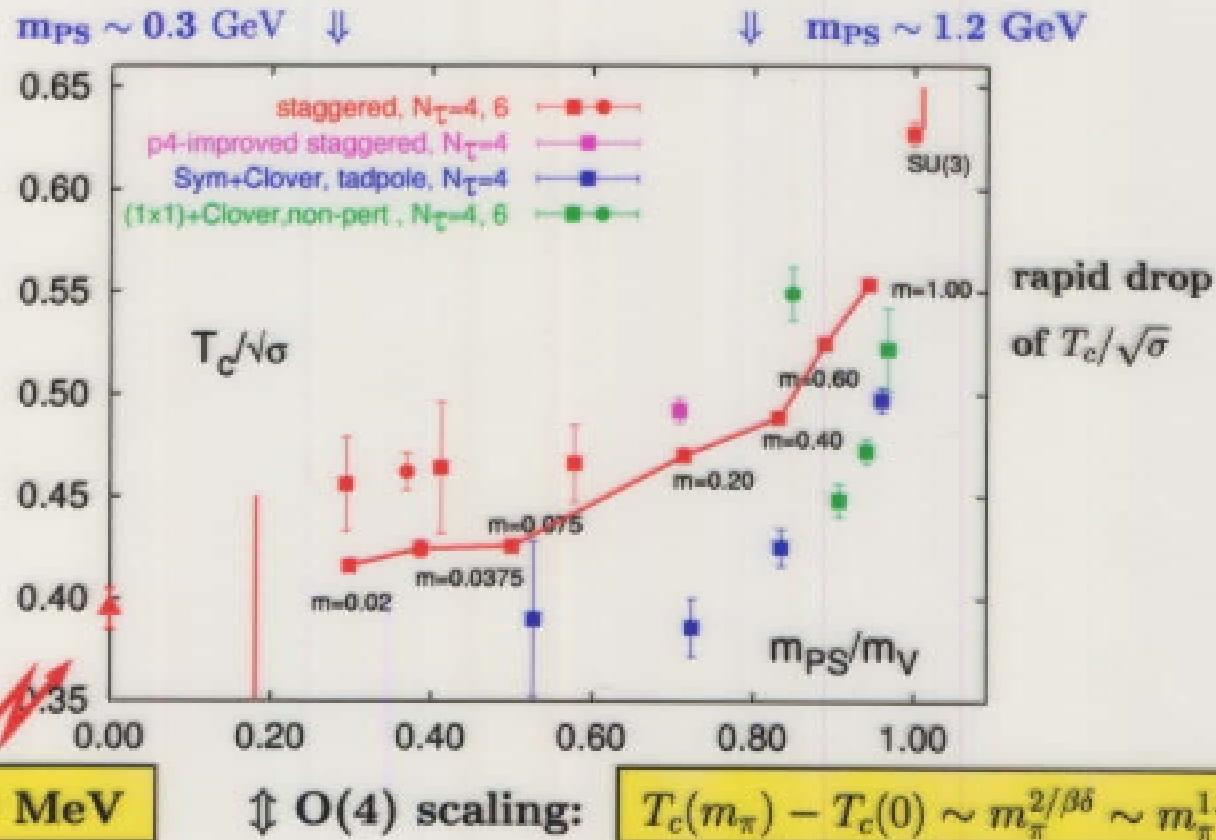

Hadrochemical Equilibration from AGS to SPS to RHIC

- Phase Diagram
- Description of Data
 - full energy SPS
 - AGS including light nuclei
 - 40 A GeV SPS
 - first RHIC data

**J. Stachel - Workshop on Thermalization and
Chemical Equilibration in Heavy Ions Collisions at RHIC
BNL July 20, 2001**

2 flavour QCD: $T_c(m_{PS})$

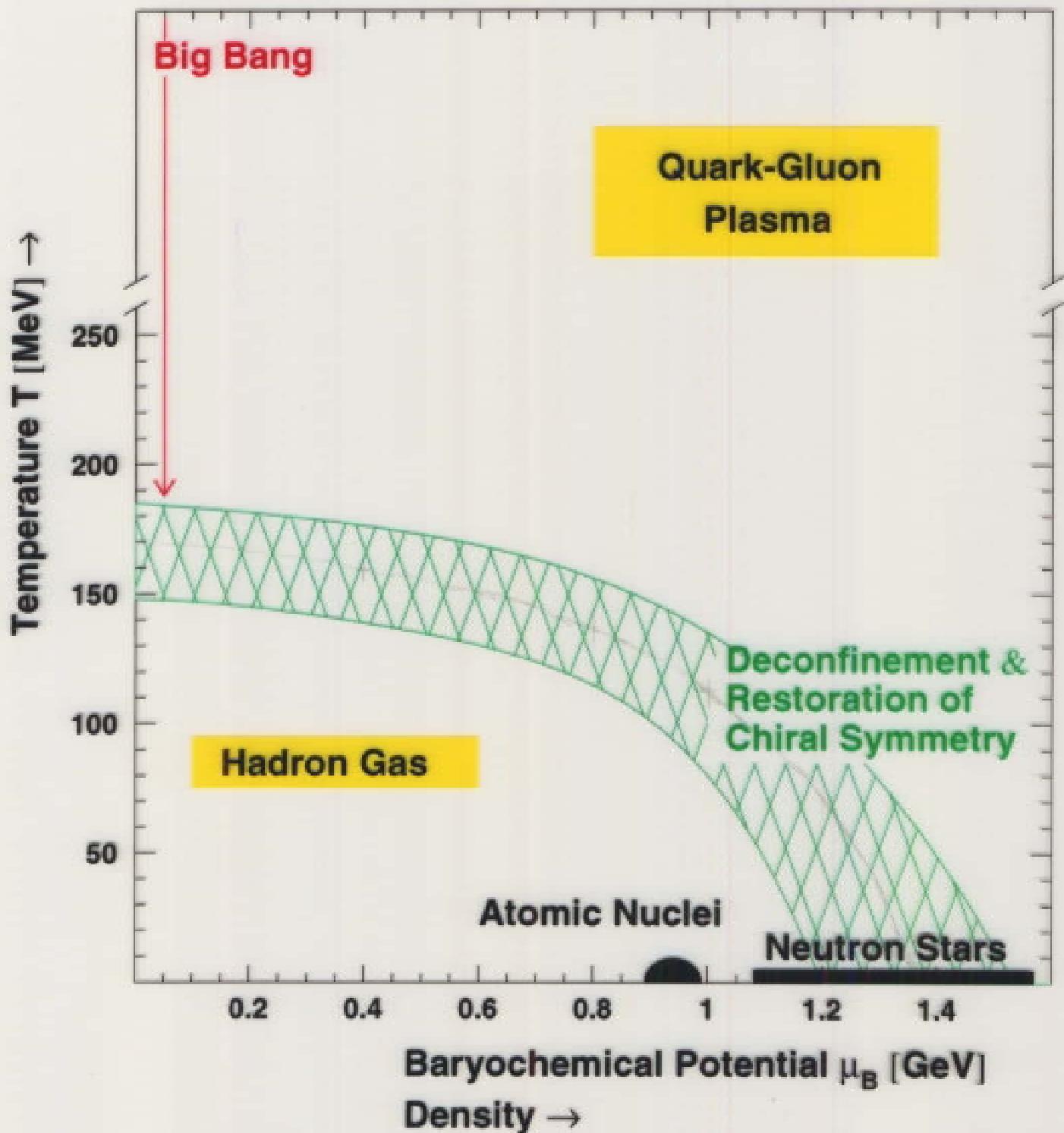


Clover: R.G. Edwards, U.M. Heller, PL B462 (1999) 132

S. Ejiri et al. (CP-PACS) hep-lat/9909075

improved staggered: Bielefeld data

domain wall fermions: D.M. Vassilev et al. (Columbia) hep-lat/9909076



Note: at $T = 170$ MeV and $\mu_B \approx 0$ effective number of degrees of freedom about 11
i.e. $3.8 g_\pi$

+
0.41
11.3

+
 $E_{hg} = 0.49 \text{ GeV/fm}^3$
 $g_{eff} = 14.3$

+

Statistical model for particle yields

- grand canonical ensemble

$$S_i = \frac{g_i}{Z^{\infty}} \int \frac{P^i dP}{\exp[(E_i - \mu_b B_i - \mu_s S_i - \mu_{I_3} I_3^i)/T]^{1/2}}$$

- use conservation laws

- baryon number $V(\sum_i n_i B_i) = Z + N$

- strangeness $\sum_i n_i S_i = 0$

- charge $V \sum_i n_i I_3^i = \frac{Z - N}{2}$

→ leaves only μ_b and T as free parameters

- excluded volume correction à la Rischke, Gorenstein et al.

$$p^{\text{excl}}(T, \mu) = p^{\text{gas}}(T, \hat{\mu}) \quad \text{with} \\ \hat{\mu} = \mu - \text{Vigen } p^{\text{excl}}(T, \mu) \\ \text{recursive ...}$$

but : different choice of excluded volume relevant distance where interaction becomes repulsive! order 0.3 fm

CERN SPS Data and Thermal Model

P.Braun-Munzinger, I. Heppe, J.Stachel
 Phys. Lett. B465 (1999) 15

Grand Canonical Ensemble:

$$\rho_i^0 = \frac{g_i}{2\pi^2} \int_0^\infty \frac{p^2 dp}{\exp[(E_i - \mu_b B_i - \mu_s S_i)/T] \pm 1}$$

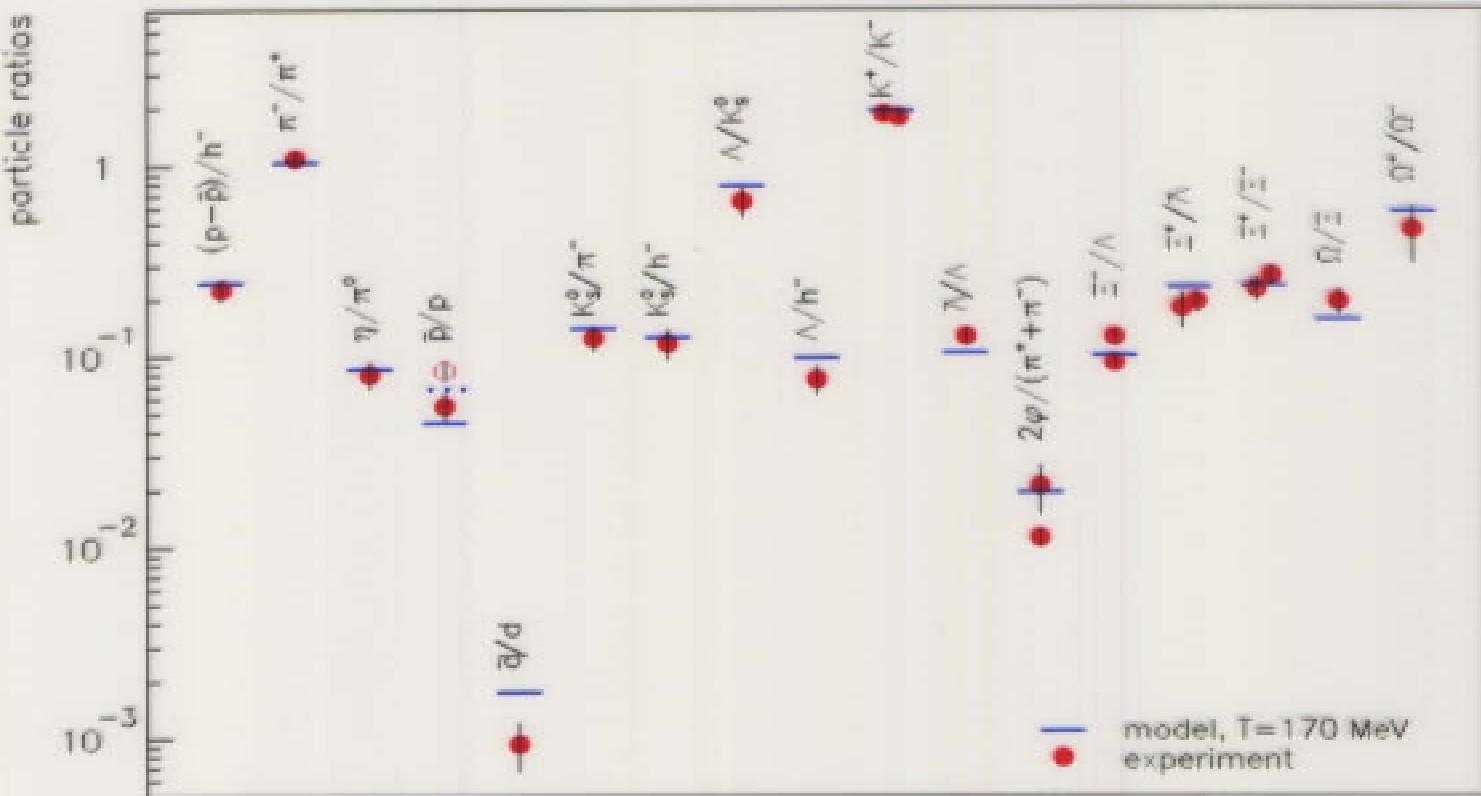
$T = 0.170 \pm 0.005 \text{ GeV}$ driven by $K_s^0/\bar{\Lambda}$, \bar{p}/p , $\bar{\Lambda}/\Lambda$, Ξ^+/Ξ^-

$\mu_b = 0.27 \pm 0.010 \text{ GeV}$ driven by p/π

$\mu_s = 0.074 \text{ GeV}$ from $\Delta S = 0$

$\mu_{I_3} = 0.005 \text{ GeV}$ from $\Delta Q = 0$

central 158 A GeV/c Pb + Pb collisions



AGS particle yields and thermal model

P. Braun-Munzinger, I. Heppe, J. Stachel, Phys. Lett. B465
(1999) 15

$$T = 125 \text{ MeV} \quad \mu_B = 540 \text{ MeV}$$

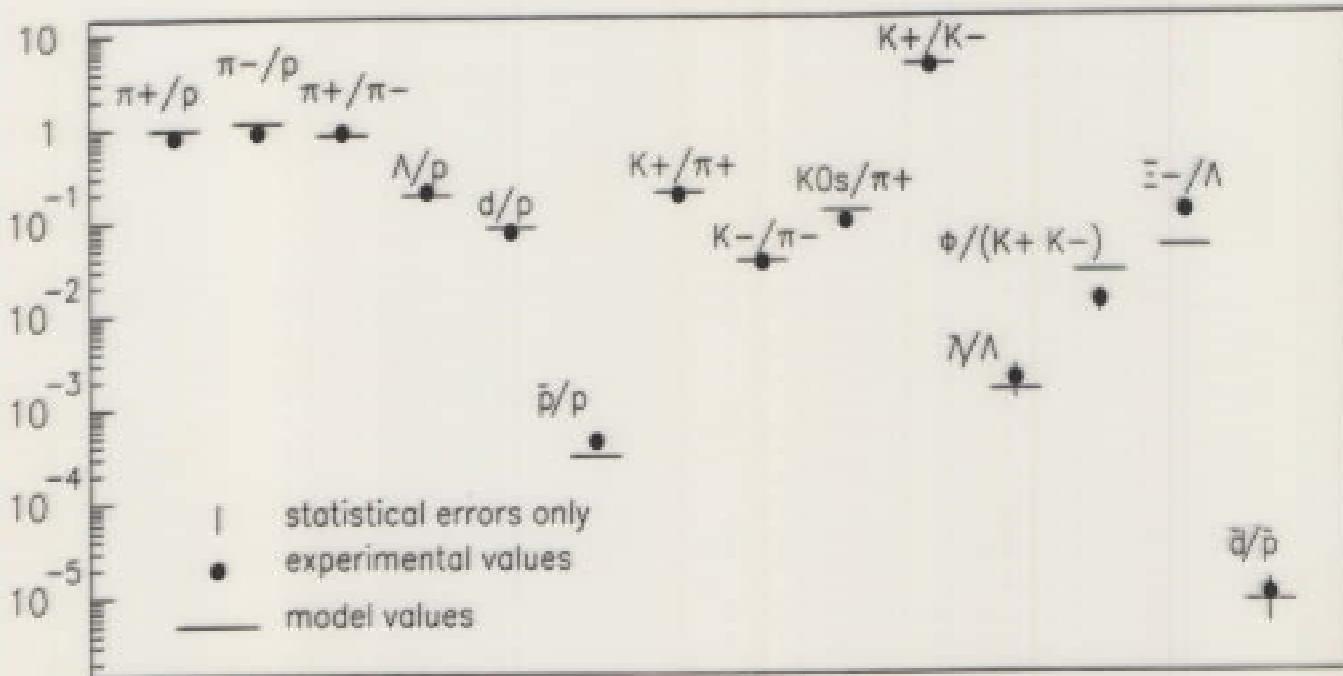
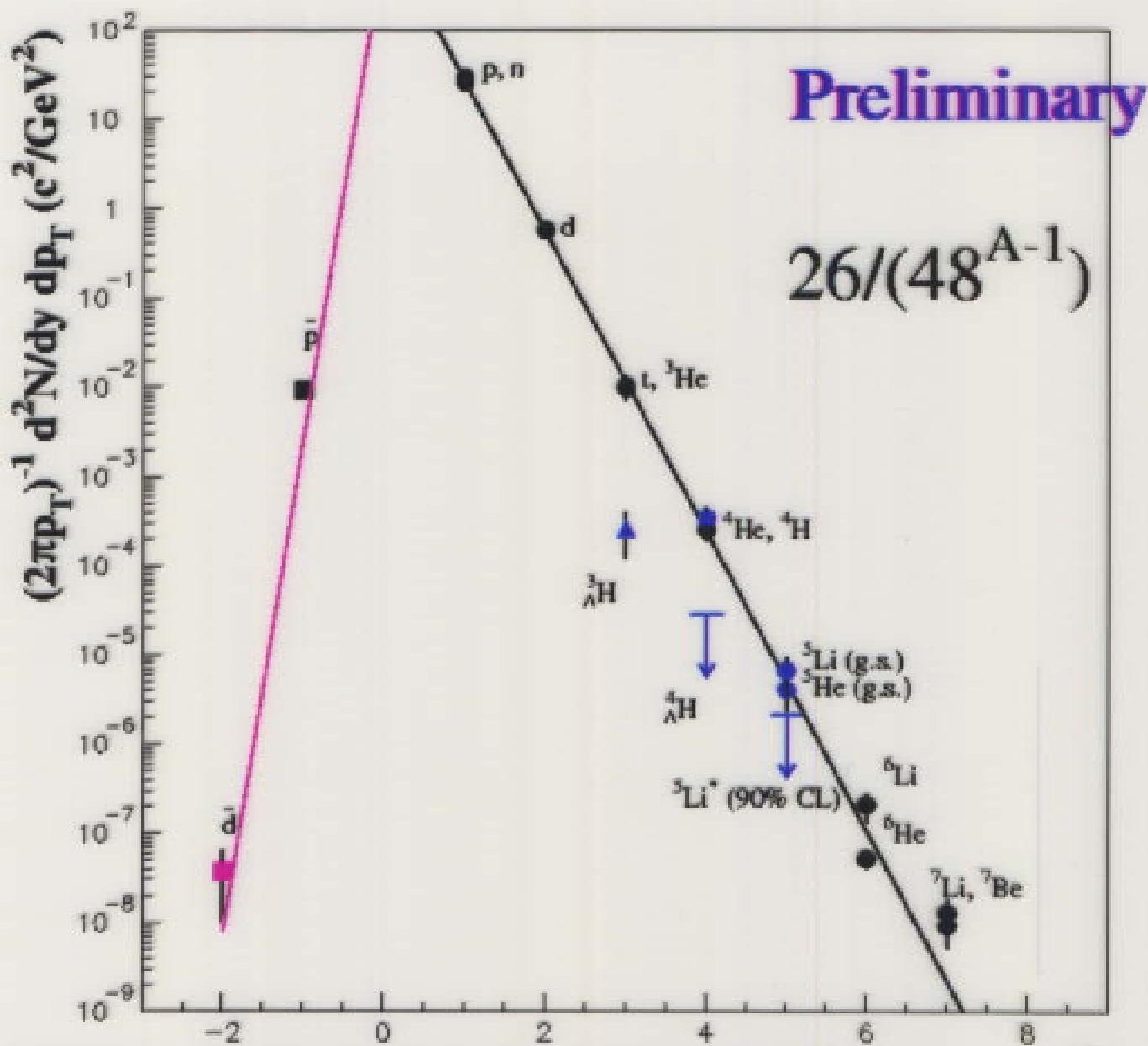


Abbildung 3.8 Hadronverhältnisse bei Si + Au(Pb) Kollisionen am AGS: Experimentelle Daten im Vergleich mit Modelldaten bei $T=125$ MeV, $\mu_B=540$ MeV, $\mu_S=116.9$ MeV, $\mu_{I_s}=-11.7$ MeV, $R(B)=R(M)=0.3$ fm.

• yields for AuAu very similar

see also: Braun-Munzinger, Stachel, Wessels, Xu
Phys. Lett. B344 (1995) 43

18 Hadrons



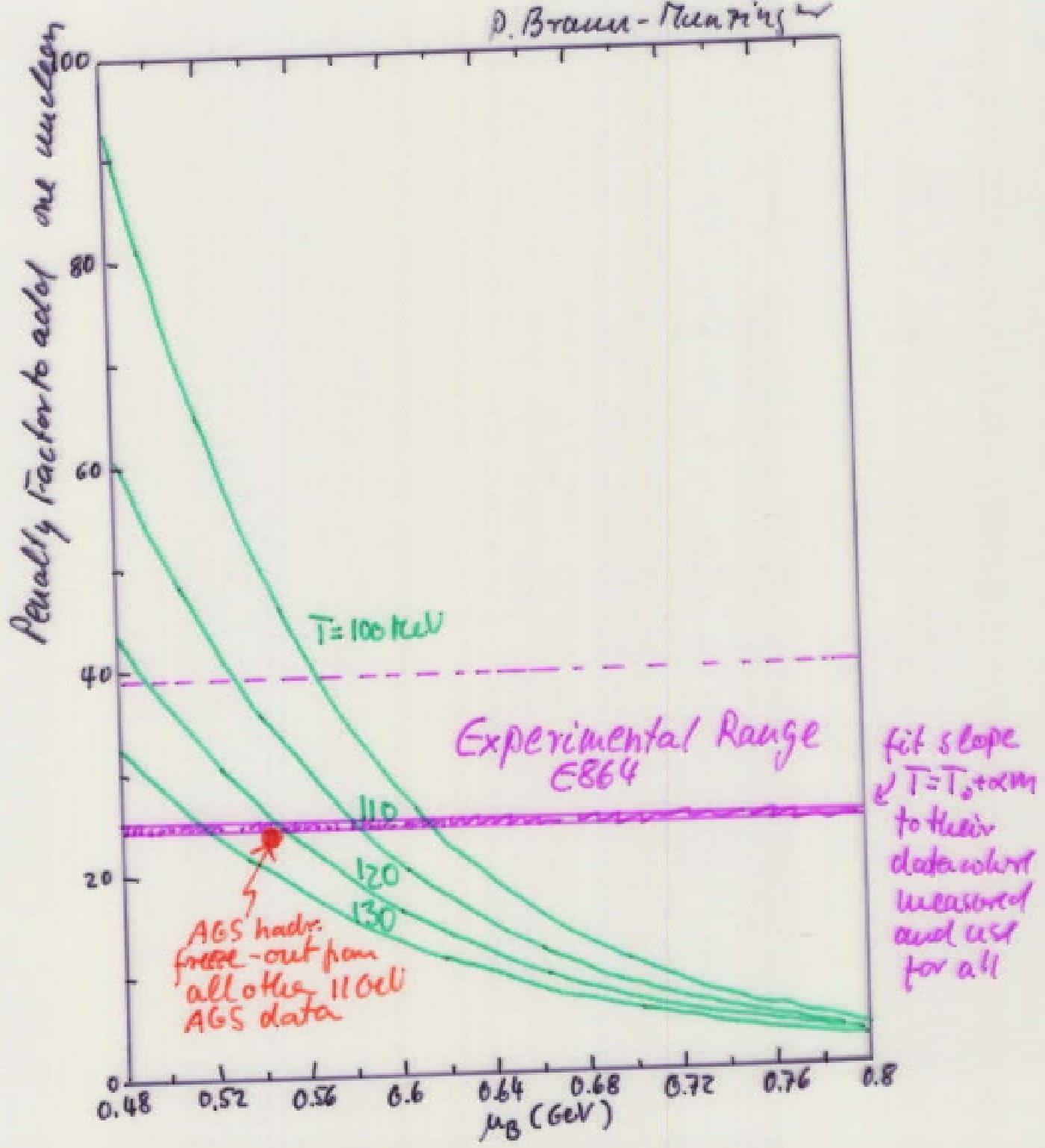
$T = 112 \text{ MeV}$, $\mu_B = 503 \text{ MeV}$, $R_g = 4 \text{ fm}$

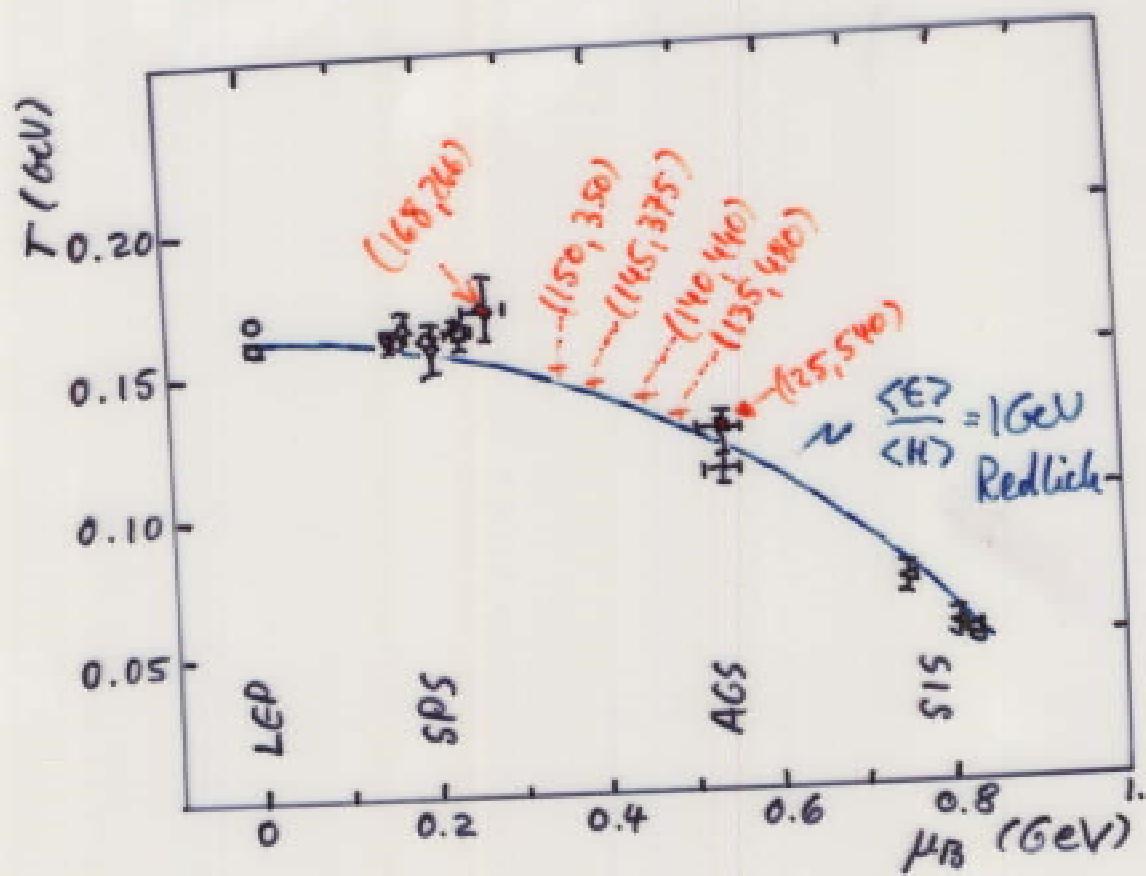
$P = 1/48$, $\lambda_S = 1/28$, $\bar{P} = 2.6 \times 10^{-6}$

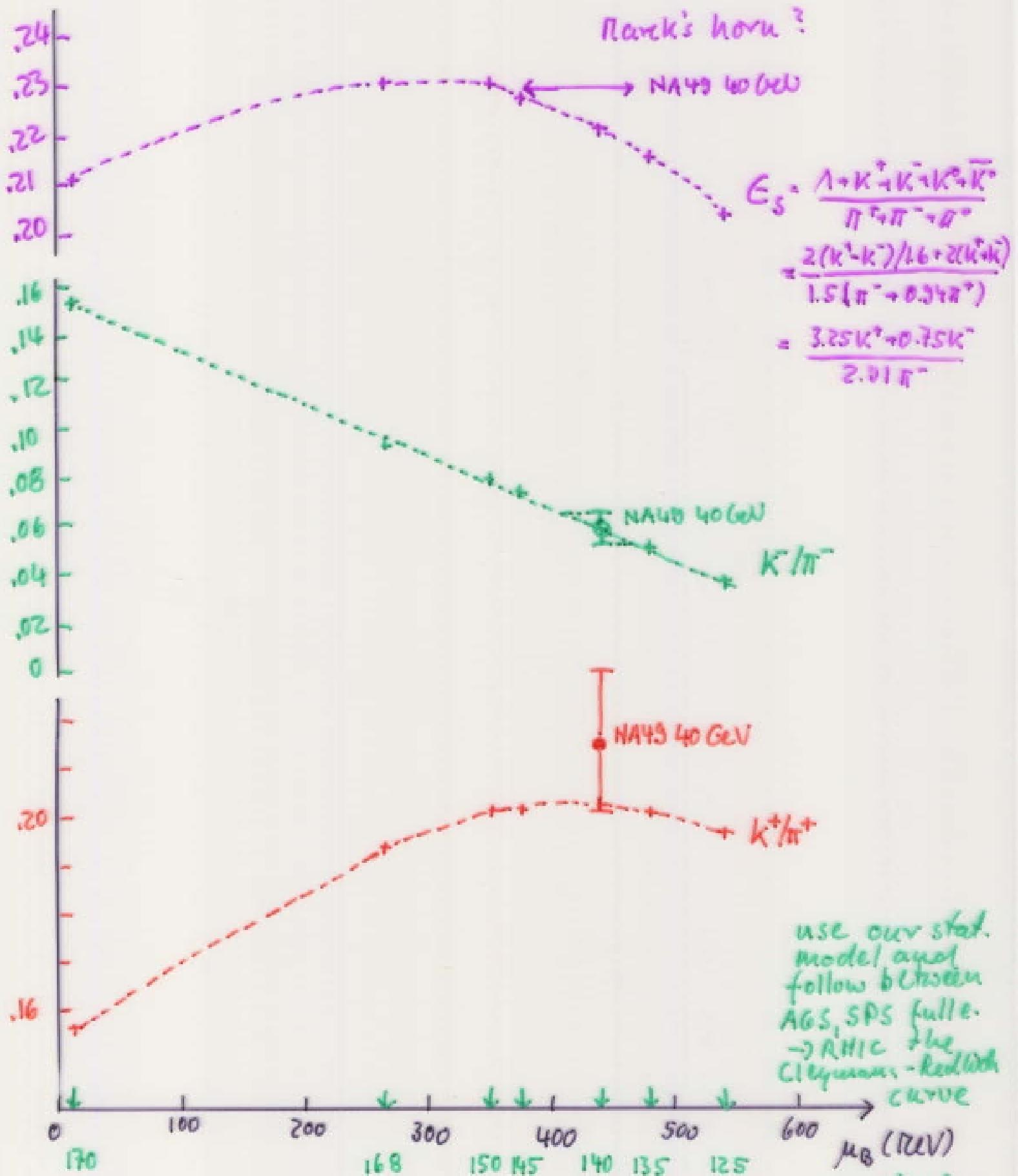
yields reproduced over 900m!

some caution; spectra not integrated over all p_T and shape is mass dependent

use slope $\propto m \rightarrow T = 135 \text{ MeV}$ upper limit







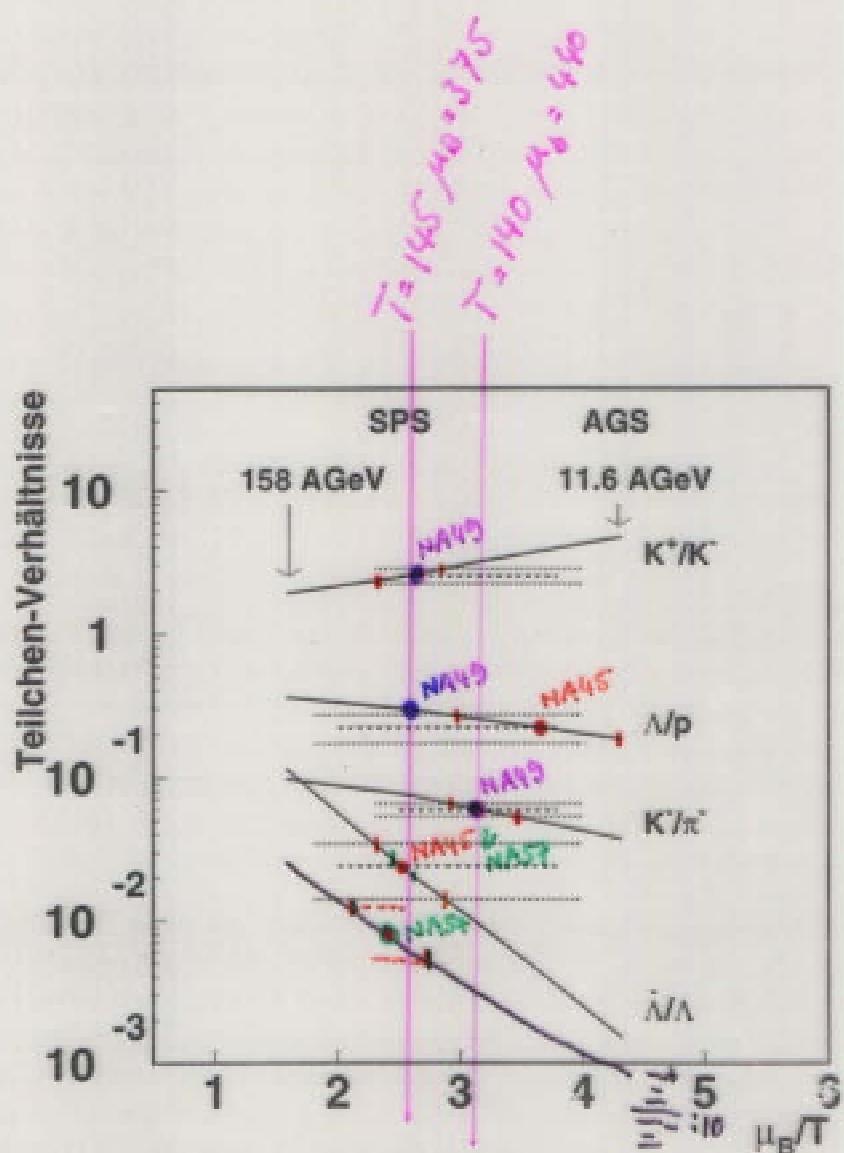
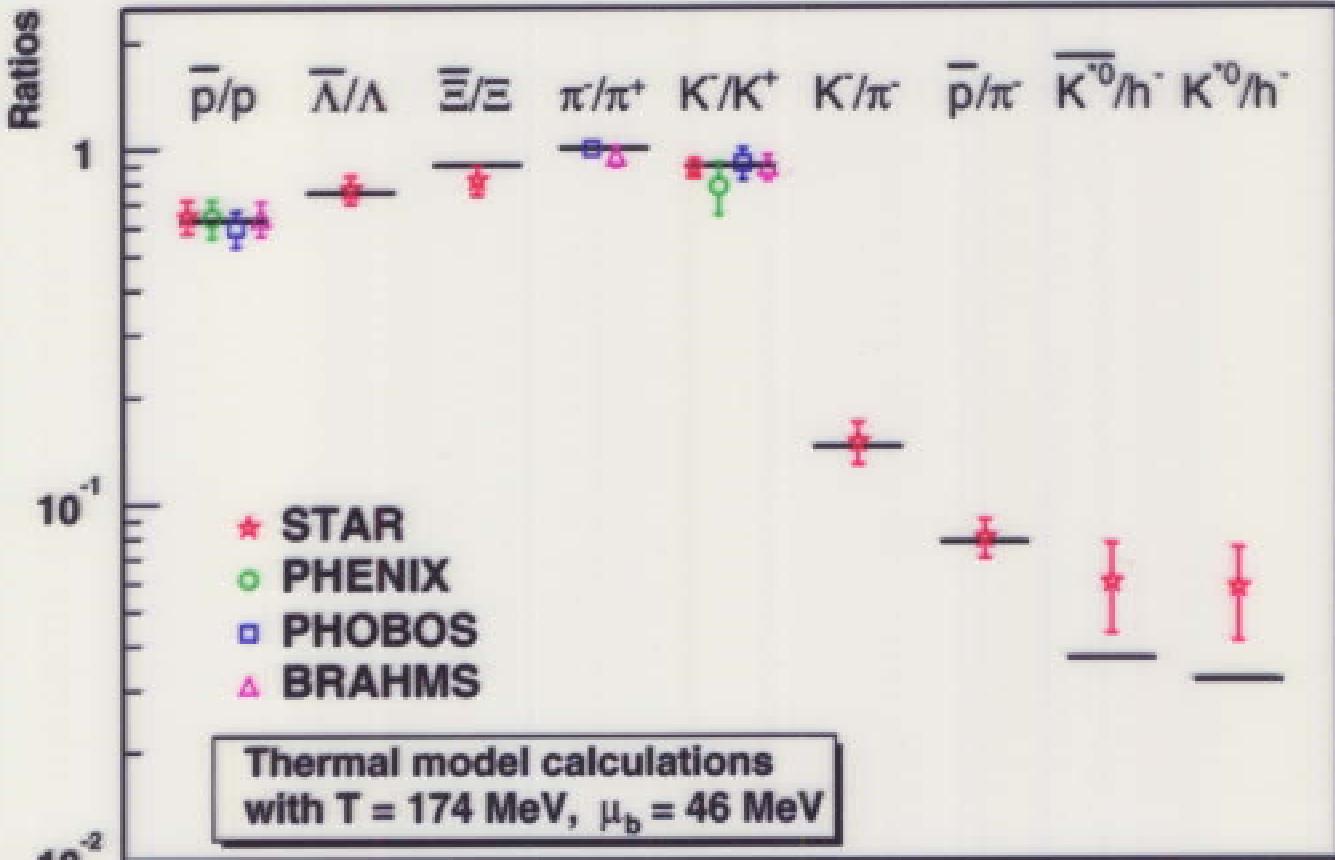


Abbildung 7.11: Mit dem thermischen Modell [15] vorhergesagte Teilchenzahl-Verhältnisse für Λ/p und $\bar{\Lambda}/\Lambda$ in Abhängigkeit vom Verhältnis μ_b/T . Eingezeichnet sind die gemessenen Teilchen-Verhältnisse bei 40 AGeV : Λ/p und $\bar{\Lambda}/\Lambda$ (NA45/CERES), K^+/K^- und K^-/π^- (NA49) [101]. Die durchgezogene Linie bezeichnet die mit dem thermischen Modell erwarteten Teilchenraten, die gestrichelten Linien geben die gemessenen Verhältnisse mit ihren Fehlergrenzen (punktierte Linien) an. (Erklärung siehe Text).

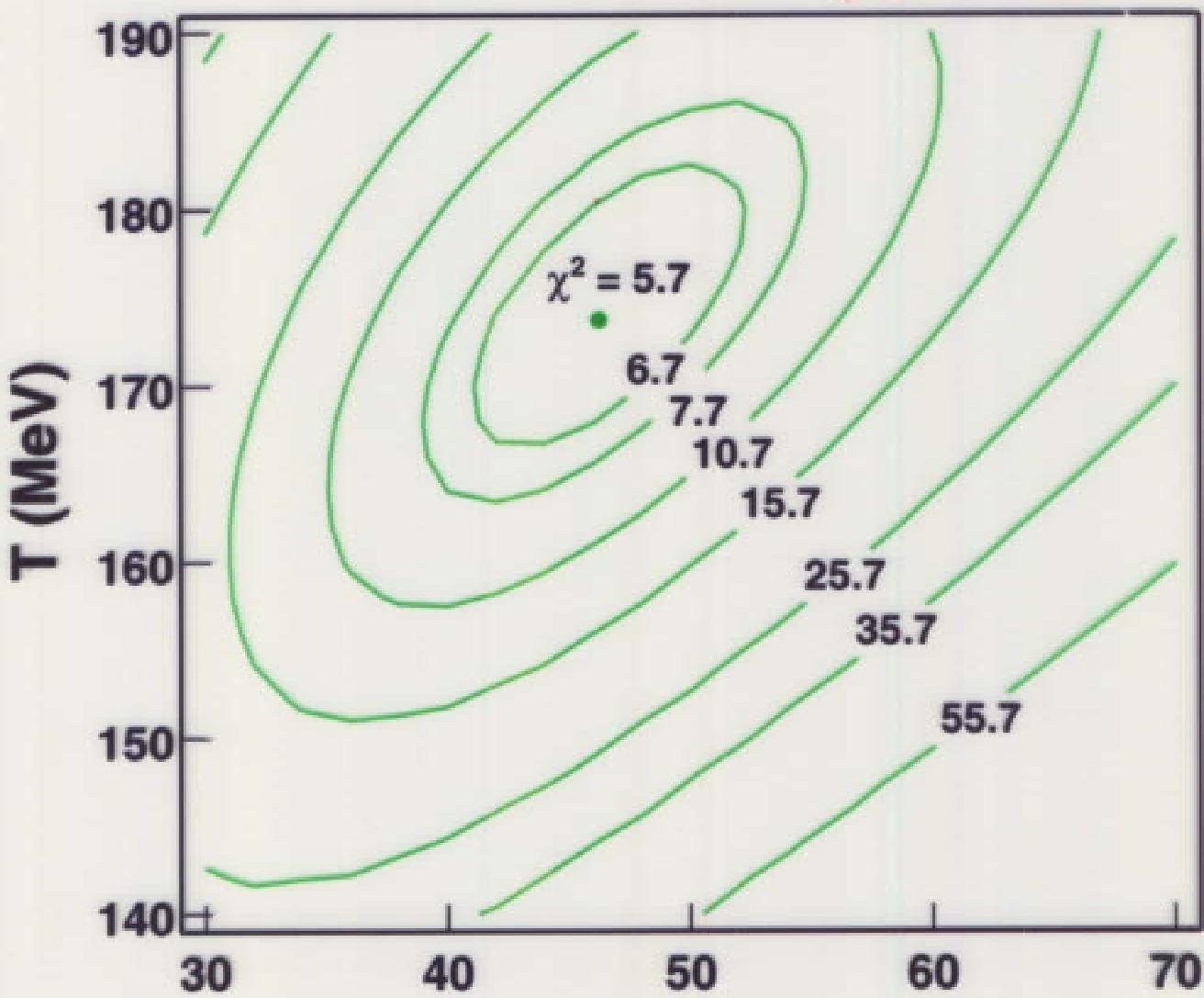
P. Braun-Munzinger, D. Magestro, K. Redlich, J. Stachel
sub. Phys. Lett. B hep-ph/0105229

50% eff. to reconstruct part. from feeding via weak decays

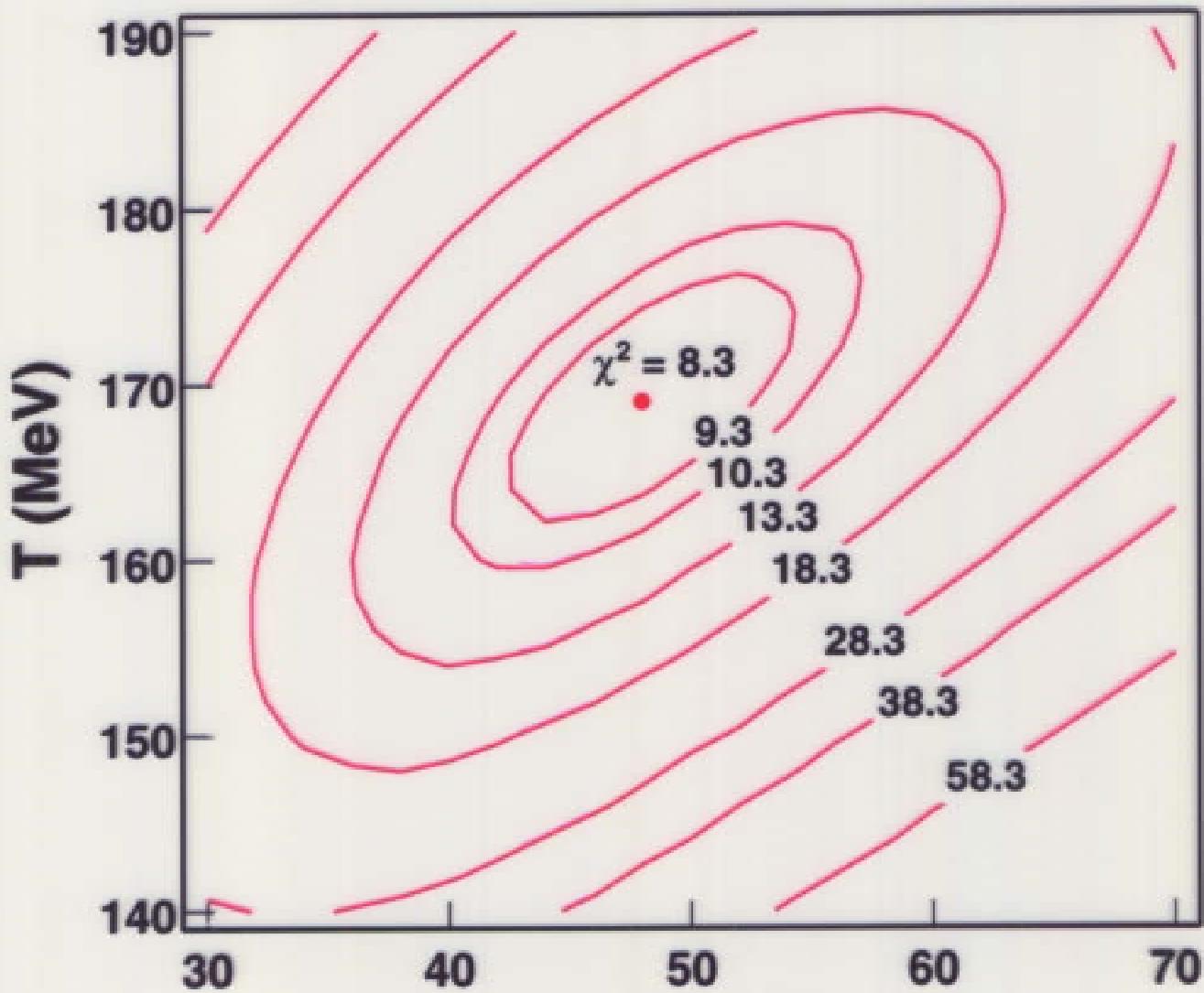


$r_w = 50\%$

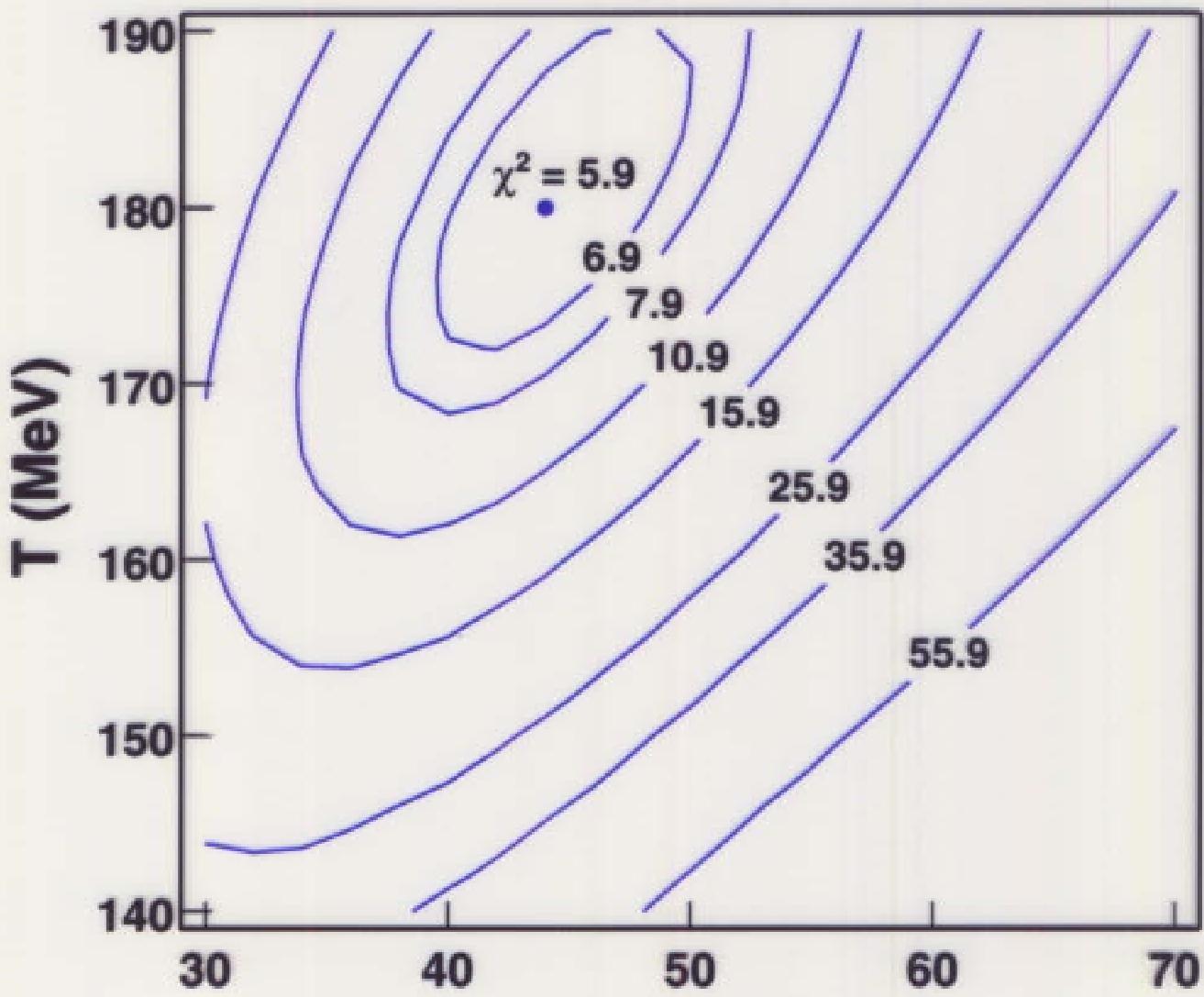
Minimum at
 $T = 174 \text{ MeV} \pm 6 \text{ MeV}$
 $\mu_B = 46 \text{ MeV} \pm 4 \text{ MeV}$

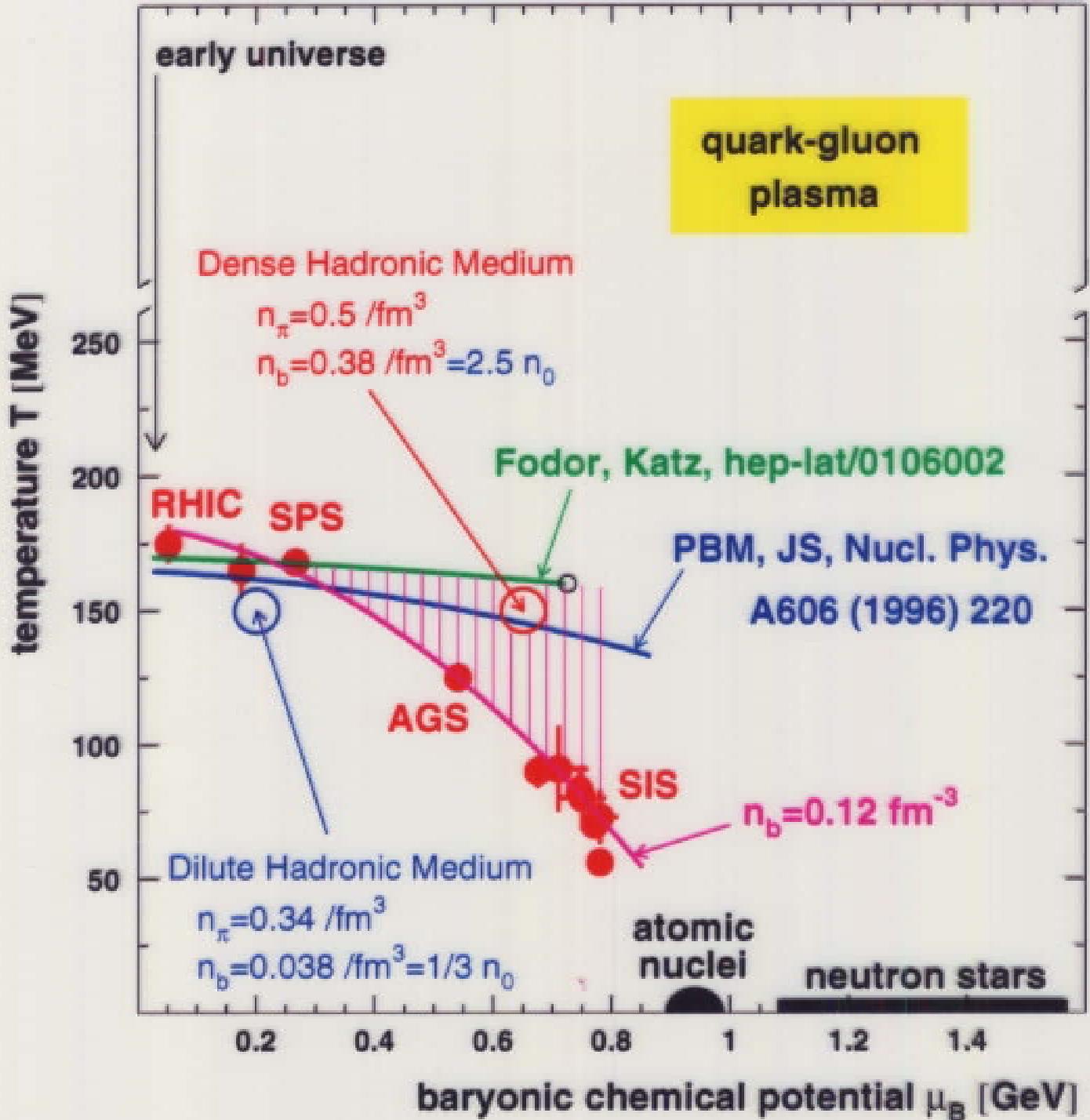


$$rw = 100\%$$
$$T = 169 \text{ MeV} \pm 5$$
$$\mu_B = 48 \text{ MeV} \pm 4$$

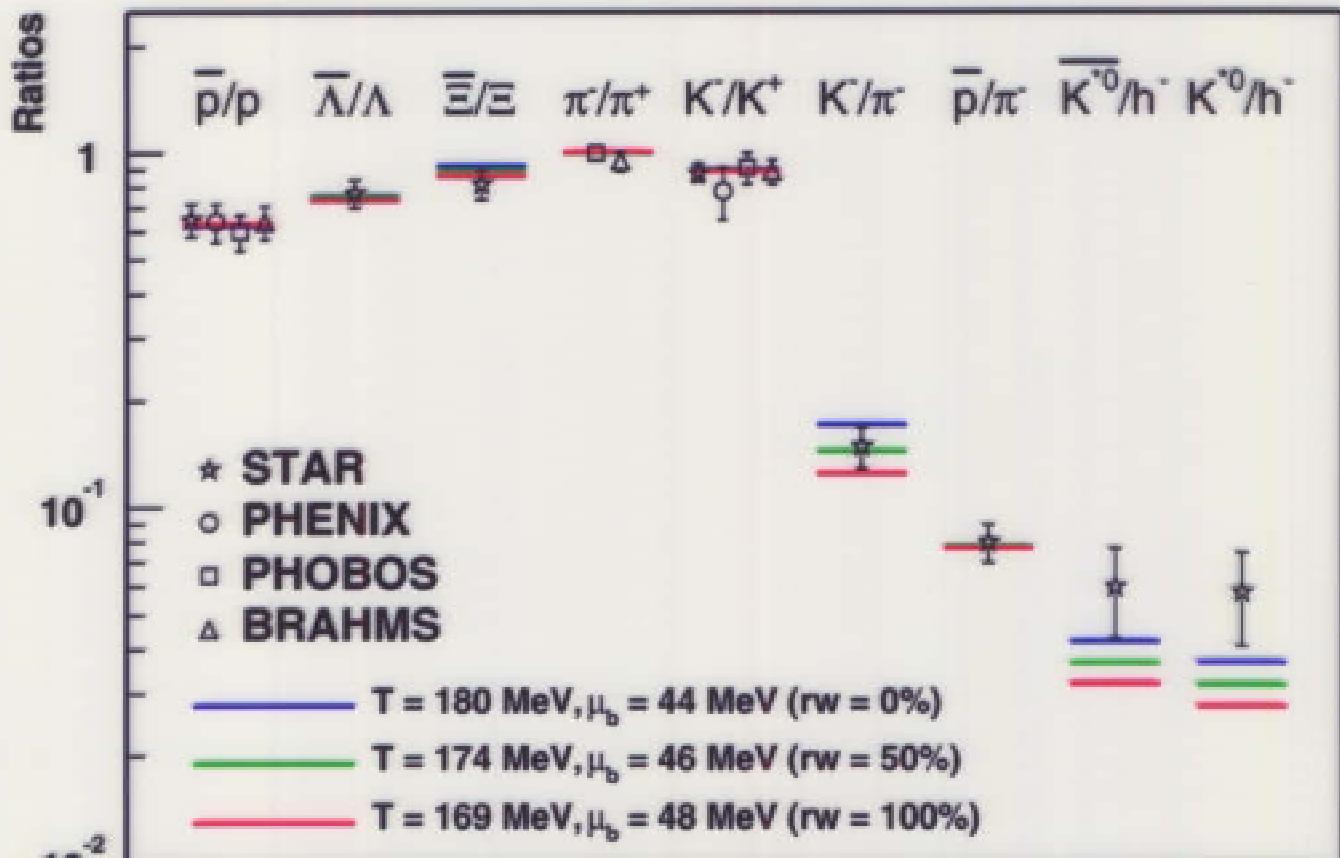


$$T = 180 \text{ MeV} \pm 7$$
$$\mu_B = 44 \text{ MeV} \pm 64$$
$$rw = 0\%$$

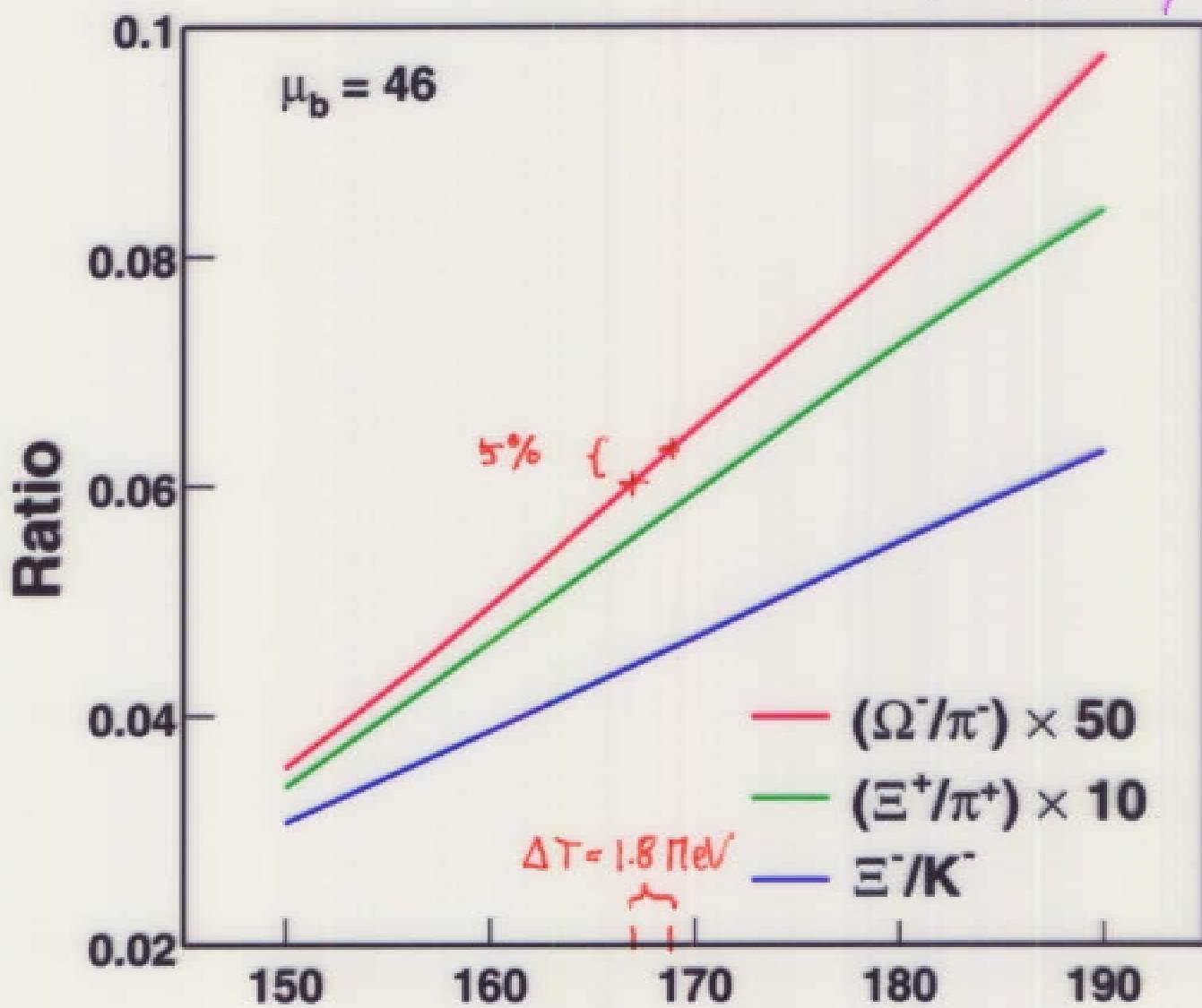




Dependence on contributions from weak decays



Ratios that will improve temperature sensitivity



- $T = 174 \pm 6 \text{ MeV}$ $\mu_B = 46 \pm 4 \text{ MeV}$
- $T = 169 \pm 5 \text{ MeV}$ $\mu_B = 48 \pm 4 \text{ MeV}$
- $T = 180 \pm 7 \text{ MeV}$ $\mu_B = 44 \pm 4 \text{ MeV}$

